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Spit-Hole Effects on the Ballistics of a 7.62-mm Cartridge

by John Ritter

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14. ABSTRACT

The U.S. Army Research Laboratory conducted a study to examine the effects of a small caliber (7.62-mm) cartridge's spit-hole on the interior ballistic performance of the cartridge. The performance metrics evaluated were cartridge pressure and muzzle velocity. The laboratory incorporated its custom breech apparatus that measures primer pocket pressure, and used standard midcase pressure measurements and high-speed imaging to evaluate early projectile motion out of a custom-built short barrel gun.

15. SUBJECT TERMS

M80, M80A1, primer force, spit-hole, interior ballistics

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1. Introduction

The U.S. Army Research Laboratory (ARL) has shown how its unique primer force measurement apparatus can be incorporated into evaluating 5.56-mm cartridge performance (*1–5*). The apparatus is unique in that it measures the axial force seen by the primer during the interior ballistic cycle. This force is proportional to the internal pressure in the primer cup. Midcase pressure measurements are also recorded through a pressure port in the barrel. Along with these measurements, a high-speed camera is incorporated into the diagnostics to examine first motion of the projectile. The high-speed video is useful when an extremely short barrel gun (approximately 1 in) is employed. With this setup the projectile tip is visible at the muzzle when the cartridge is in its initial loaded position in the chamber. This evaluation technique has also gained traction with researchers at the U.S. Army Armament Research, Development and Engineering Center (*6*).

These techniques for studying early time ballistics have been transitioned into a new 7.62-mm breech that functions in a similar manner to the 5.56-mm predecessor. This report will document the validation of the new apparatus, establish baseline data for the M80, evaluate a developmental M80 cartridge (henceforth named M80 "A"), and briefly investigate the influence the cartridge's spit-hole area plays in ballistic performance. The spit-hole is the narrow pathway between the cartridge's primer pocket and propellant chamber. All of these experiments were conducted in a short barrel gun with a reduced chamber leade. Mil-spec leade for the M14 is 0.040 in (*7*); however the chamber leade for these experiments is 0.025 in. Since the short barrel gun is being incorporated, a Phantom high-speed camera is also used in the diagnostic suite to characterize initial projectile motion and velocity.

2. Approach

2.1 Fixture Design

The breech apparatus implemented for the experiments is the ARL designed fixture that measures primer force. In this set of experiments, the breech was mated to a barrel of approximately 1 in length. The short barrel retains 0.50 in (12.7 mm) of rifling. The midchamber pressure transducer, Kistler Model 6215 (*8*), is consistent with previous experiments. Pressure is measured through a 3/32-in hole drilled into the cartridge case, forward of the midpoint. Case holes are sealed with 1-mil-thick DuPont Kapton* tape. The force transducer selected is the

*Kapton is a registered trademark of E.I. du Pont de Nemours and Company.

Kistler Model 9031A Load Washer (*9*). Force transducer selection was driven by the anticipated load and the necessity of an annular design to allow passage of the firing pin through the transducer. Figure 1 illustrates important setup details of the apparatus and shows where the barrel was shortened as indicated by the red line.

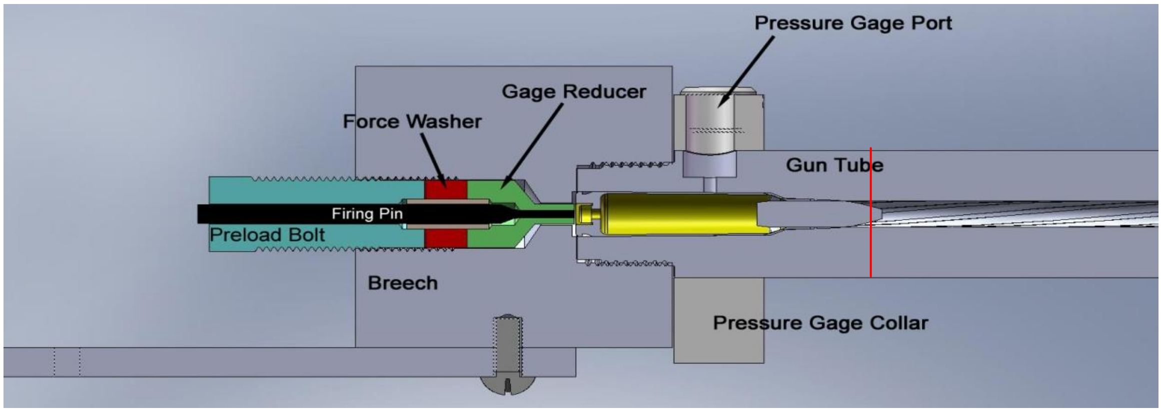

Figure 1. Detail view of 5.56-mm instrumented barrel and breech.

2.2 Experiment Setup

Experiments were performed using the primer force measurement breech to gain insight into interior ballistic (IB) performances of the 7.62-mm cartridge. Both M80 and M80 "A" cartridges were evaluated. In addition, an experiment was set up to evaluate the influence of the cartridge's spit-hole area.

The effort began as a prove-out of the new breech apparatus; therefore, the first experiment fired primer-only cases to generate a primer force reading. This evolved into an experiment where the spit-hole area was altered to determine the effects this would have on the primer pocket pressure. Figure 2 shows a cartridge cutaway highlighting the spit-hole region. The nominal M80 spit-hole diameter is 0.078 in (*10*), but for our reduced area experiments a hole of 0.055 in diameter was employed, a reduction in area of 50.3%. Once the apparatus prove-out was completed, experiments were conducted to establish a baseline performance for the M80 and M80 "A" cartridge in the short barrel gun. Fully loaded M80 cartridges with modified spit-holes were also fired.

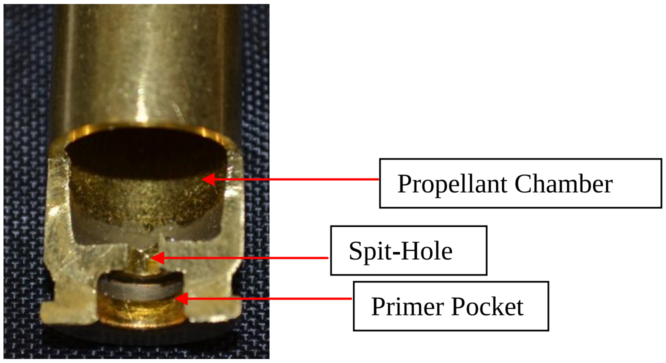

Figure 2. Standard 7.62-mm cartridge cutaway.

A Phantom V7.3 high-speed camera was used with the short barrel gun. The camera records early time motion of the projectile, which is used to calculate velocity. The high-speed camera was able to record video at a frame rate of 97,560 fps with a resolution of 224 × 72 pixels. All distances in the following figures reference the initial position of the projectile tip as zero. All time references use the initial peak of the primer output as zero. Primer force data are recorded as arbitrary units (a.u.), not pressure, in an effort to distinguish the graphical results from the midcase pressure results. For conversion purposes, 1 a.u. is equal to 400 lbf. The M80 cartridges are from production lot LC-07C603L664. The M80 "A" cartridges are comprised of a standard M80 case with a developmental projectile and powder. Pressure and force data are reported as a five shot average.

3. Results

3.1 Prove-Out, Primer Only

Prove-out of the newly designed 7.62-mm breech fixture was performed to ensure the apparatus functioned as designed; therefore, primer-only cartridges were initially fired. There were difficulties recording the data from the primer-only shots because the no. 34 primer does not produce a significant force output. Triggering thresholds were modified to aid collection. Figure 3 illustrates the relative amplitude of the initial output peak from the 7.62-mm no. 34 primer compared to the no. 41 primer of the 5.56-mm cartridge.

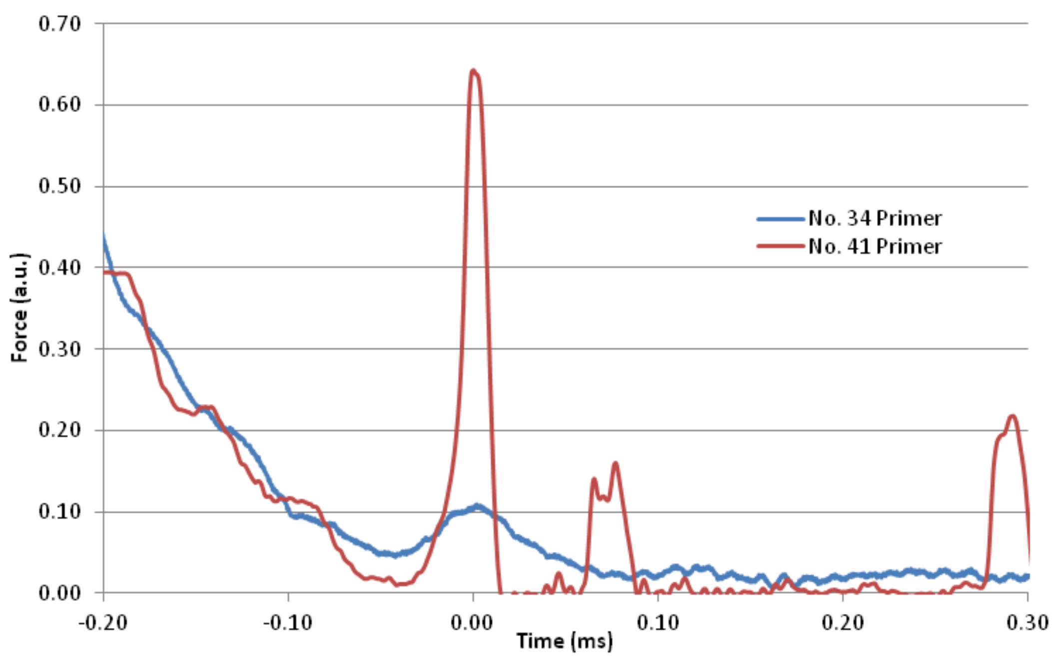

Figure 3. No. 34 (7.62-mm) and no. 41 (5.56-mm) primer outputs.

The results in figure 3 show the system starting with a preload on the force washer (0.40 a.u.), then the firing pin strikes the primer 'relaxing' most of the preload. Finally, the primer functions and output is recorded. The peak of the initial primer output is referenced as t_0 for pressure and motion data.

After prove-out was completed, an experiment was conducted to determine what effect the spit-hole area had on the primer force output. It was hypothesized that if the gas flow was choked through the spit-hole, then the pressure within the primer pocket would increase. For this experiment the spit-hole diameter was reduced from the mil-spec 0.078 in to 0.055 in. As figure 4 illustrates, this reduction in area increased the force exerted on the primer cup by 20 times when compared to the no. 34 primer output.

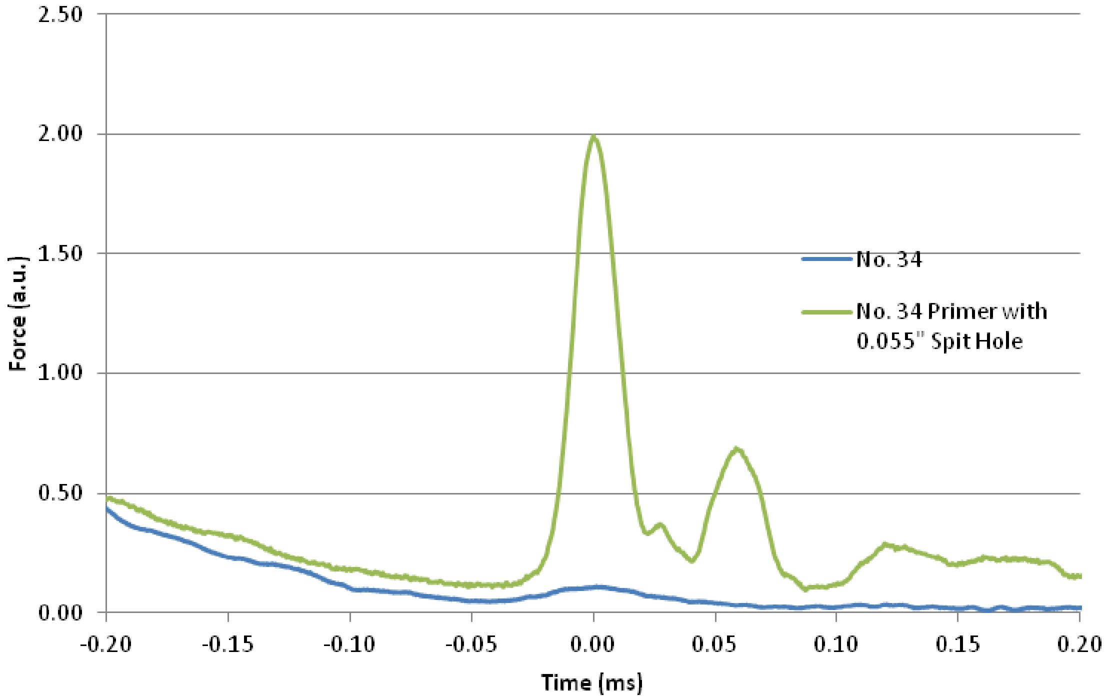

Figure 4. No. 34 primer with smaller, 0.055-in spit-hole.

3.2 M80, M80 "A," and M80 With Reduced Spit-Hole Area

Following the successful fixture prove-out experiments, a baseline primer force for the M80 and M80 "A" cartridges was established to compare with future experiments. The reduced spit-hole area experiment was also expanded to include M80 loaded cartridges. All the data were generated using the short barrel with reduced chamber leade.

Pressure and force data are illustrated in figure 5 for the various experiments. For clarity, the primer force measurements are only shown up to 350 µs. M80 "A" chamber pressure was not recorded, as the fixture had not been equipped with a pressure tap at the time of the experiment.

The baseline M80 and M80 "A" results do not show anything unusual. The initial primer output is nearly identical, and the pressure rise is a little sooner in the M80 "A" due to its faster burning propellant. The force associated with the M80 "A" propellant charge output is first seen at 250 µs, whereas the M80 output is seen at 300 µs.

When the cartridge with reduced spit-hole area is employed, there is a noticeable difference in the primer force response. The initial primer spike is greatly enhanced, with about 350% more pressure in the primer pocket during initial output. This much pressure in the primer pocket would not be desirable under any operating condition. The smaller spit-hole also resulted in the main charge burning sooner when compared to the baseline M80. In figure 5, the initial rise of the chamber pressure occurs about 50 µs sooner, and the peak pressure is reduced 1500 psi.

The M80 and modified spit-hole M80 were also evaluated in a full length Mann barrel with a length of 22.25 in. The pressure curves were very similar to those shown in figure 5, with only a 500-psi difference in average peak pressure. The muzzle velocities were also similar, with the M80 averaging 844.1 m/s and the modified spit-hole M80 averaging 843.7 m/s. The only noticeable difference between the two cartridges was the calculated standard deviation in velocity. The M80 had a standard deviation (SD) of 5.98 m/s, while the modified spit-hole M80 had an SD of 4.17 m/s, a reduction of 30%. The evaluation represents a 10 shot average for each cartridge type.

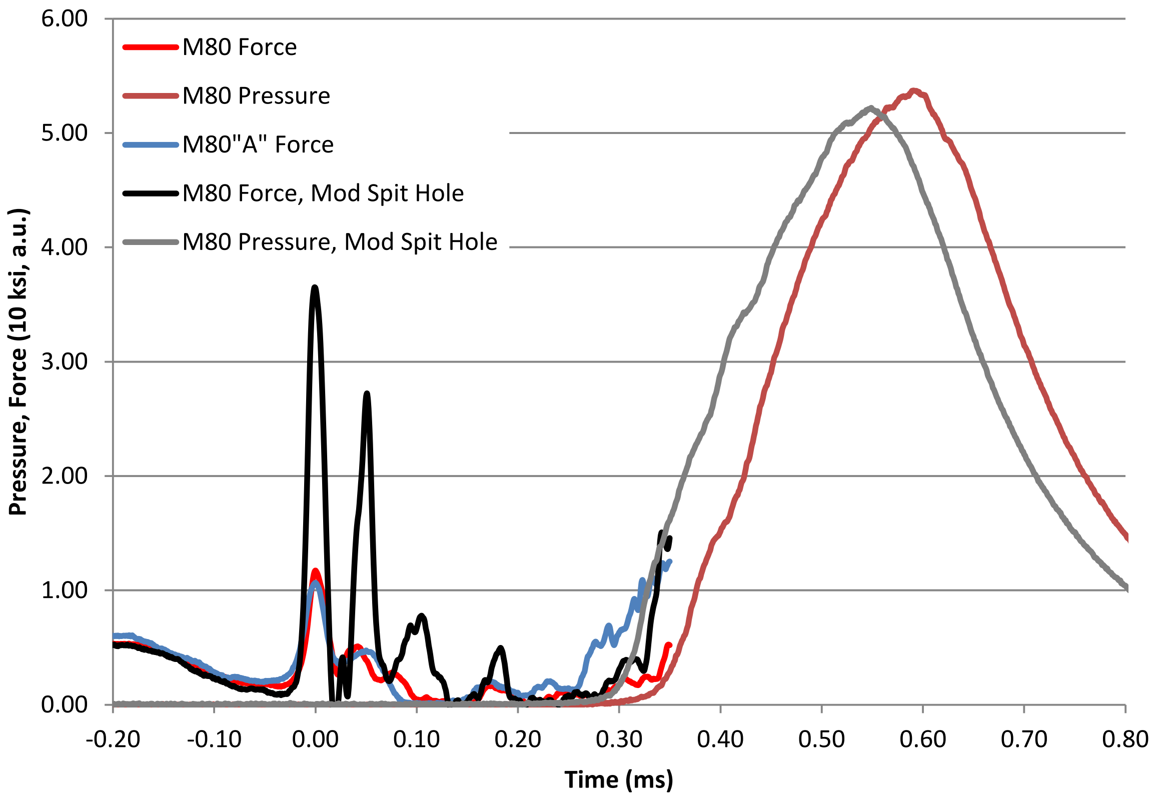

Figure 5. Pressure and force data of 7.62-mm cartridges in the short barrel.

Examination of the motion and pressure of the individual shots yielded interesting results. For the baseline M80 cartridge there was some inconsistency with performance. Namely, two of the five shots achieved a peak midcase pressure 5000 psi greater than the others. From video evidence, these two shots also exhibited a tremendous amount of propellant blow-by early in the ballistic cycle. Figure 6 is a still image from the video where (a) there was early blow-by associated with higher overall peak pressure causing the projectile to be obscured, and (b) a more controlled projectile exit from muzzle where a clean image is still being recorded at a later time. The muzzle is on the left edge of the image and the overall frame width is just over 1 in.

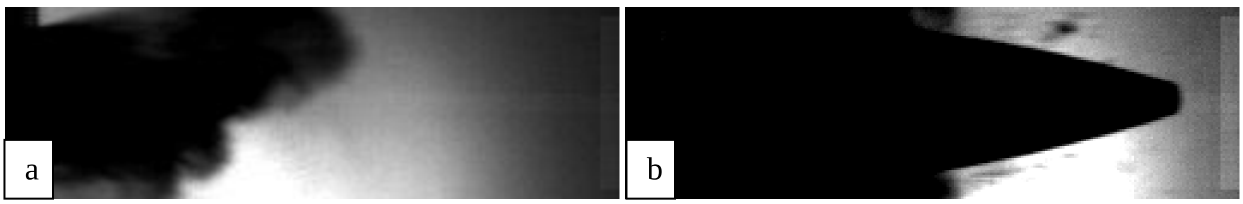

Figure 6. Images of M80 exiting the muzzle, (a) higher peak pressure and early blow-by and (b) more controlled exit, representative of most shots.

Figure 7 shows the individual position plots for the M80 cartridges. Shots 7 and 10 are the two with the higher pressure, and it is observable that their respective slopes (velocity) are greater than the other rounds at the time the images were obscured.

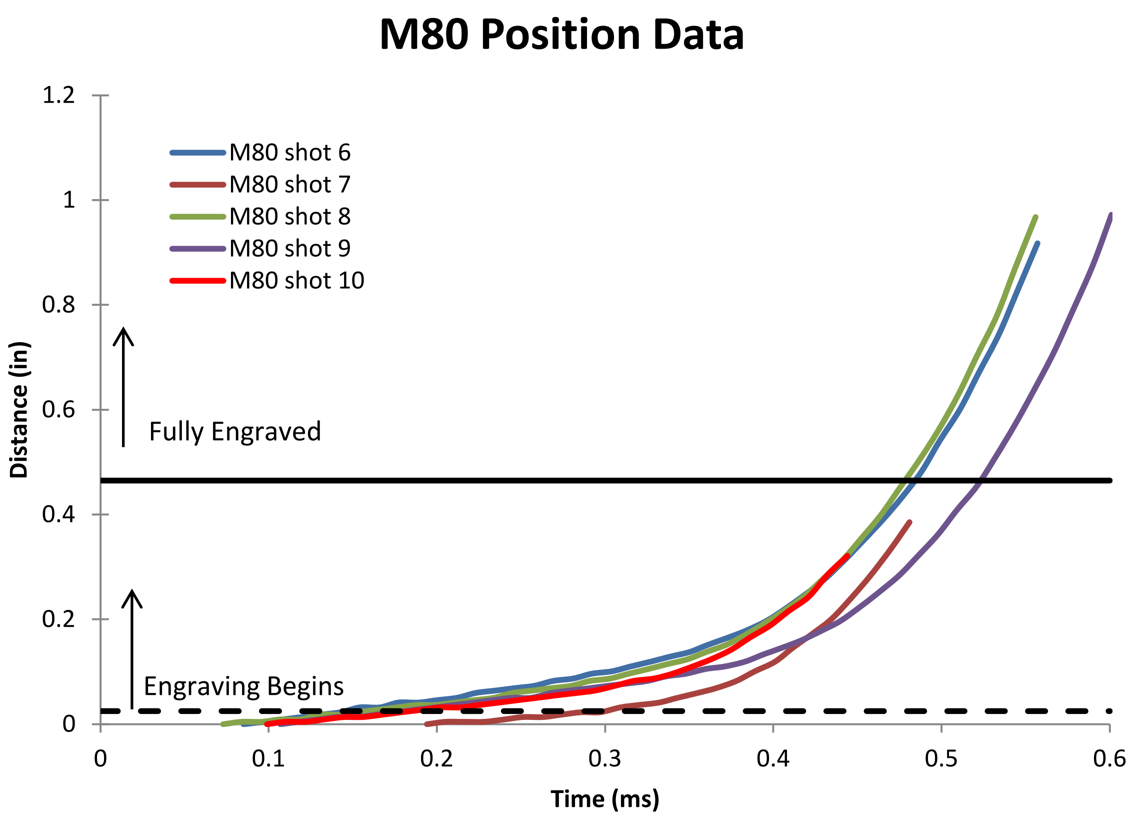

Figure 7. Position data for the M80 projectile.

The videos associated with the M80A1 and the modified M80 spit-hole did not encounter any issues associated with blow-by obscuring the images. Individual position data were also more consistent between 0 and 250 µs with the M80A1 and modified M80 cartridges, as shown in figures 8 and 9, respectively. As the figures show, all the projectiles experienced a tendency to diverge after travelling about 0.100 in. This divergence is likely a product of variability associated with initial projectile engraving forces. Recall that the leade of the barrel is only 0.025 in; therefore, when the divergence occurs, the projectile has already begun the engraving process. Total linear distance of engraving on a projectile is 0.44 in, so by the time the projectile reaches 0.50 in of travel it is fully engraved. Figure 10 illustrates an engraving mark on a recovered projectile. After 0.50 in of travel, the motion of the projectiles is very consistent. Figure 11 plots the position of the respective rounds after 0.50 in of travel to illustrate this point. This leads to the conclusion that a great deal of variability in cartridge performance may be attributed to the variability associated with the initial engraving process. This assertion is supported by the calculated velocities of the figure 11 slopes are all between 200 and 220 m/s. Velocity data are accumulated in the appendix.

One issue arose with the fidelity limitations of the Phantom V7.3 camera. When a small viewing area of 1 in, and a resolution of 224 × 72 pixels is used, the smallest measureable position increment per time step corresponds to a velocity of approximately 10 m/s. At times, motion was visible between consecutive images even though the point of the bullet remained within the same pixel. This resulted in a calculated zero velocity for some frames with apparent motion. In the future, a higher resolution will be necessary to overcome this limitation at low velocities.

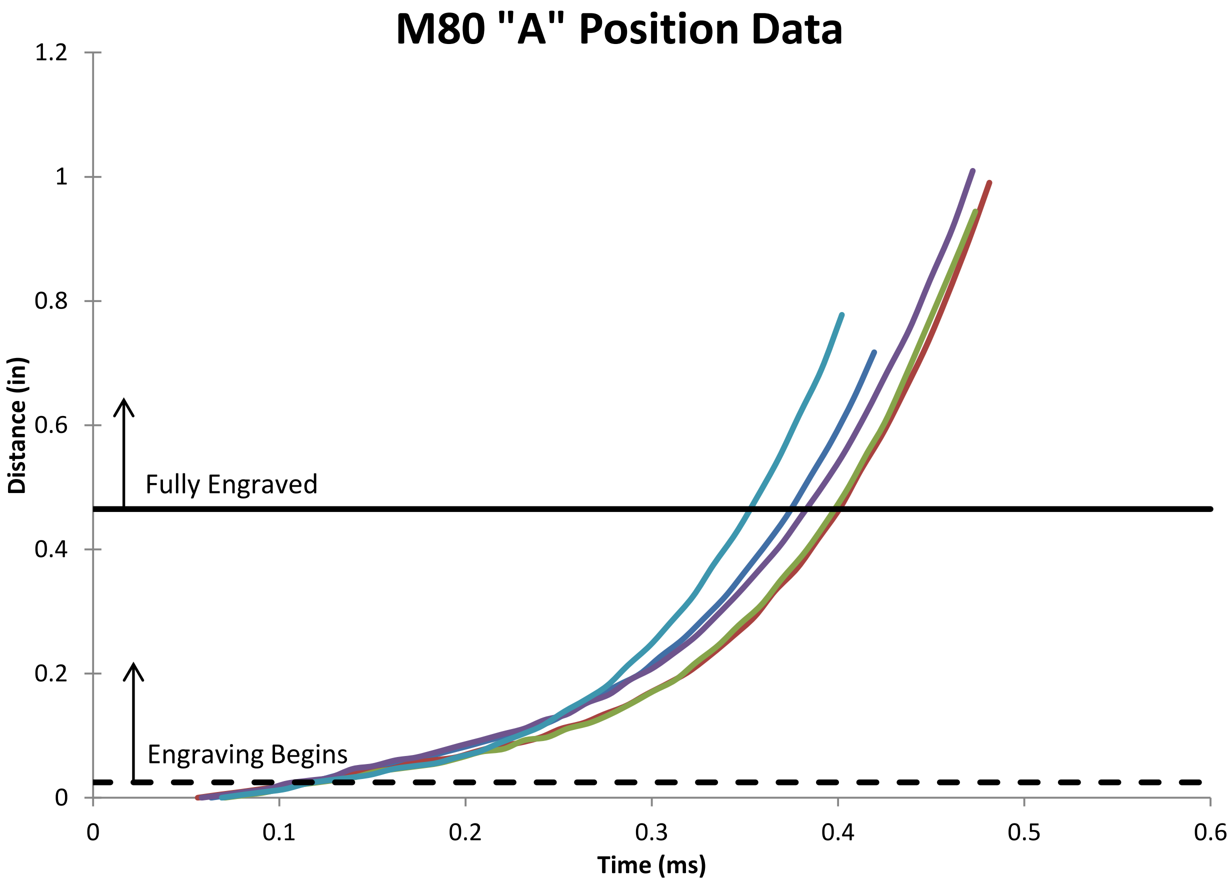

Figure 8. Position data for individual M80 "A" shots.

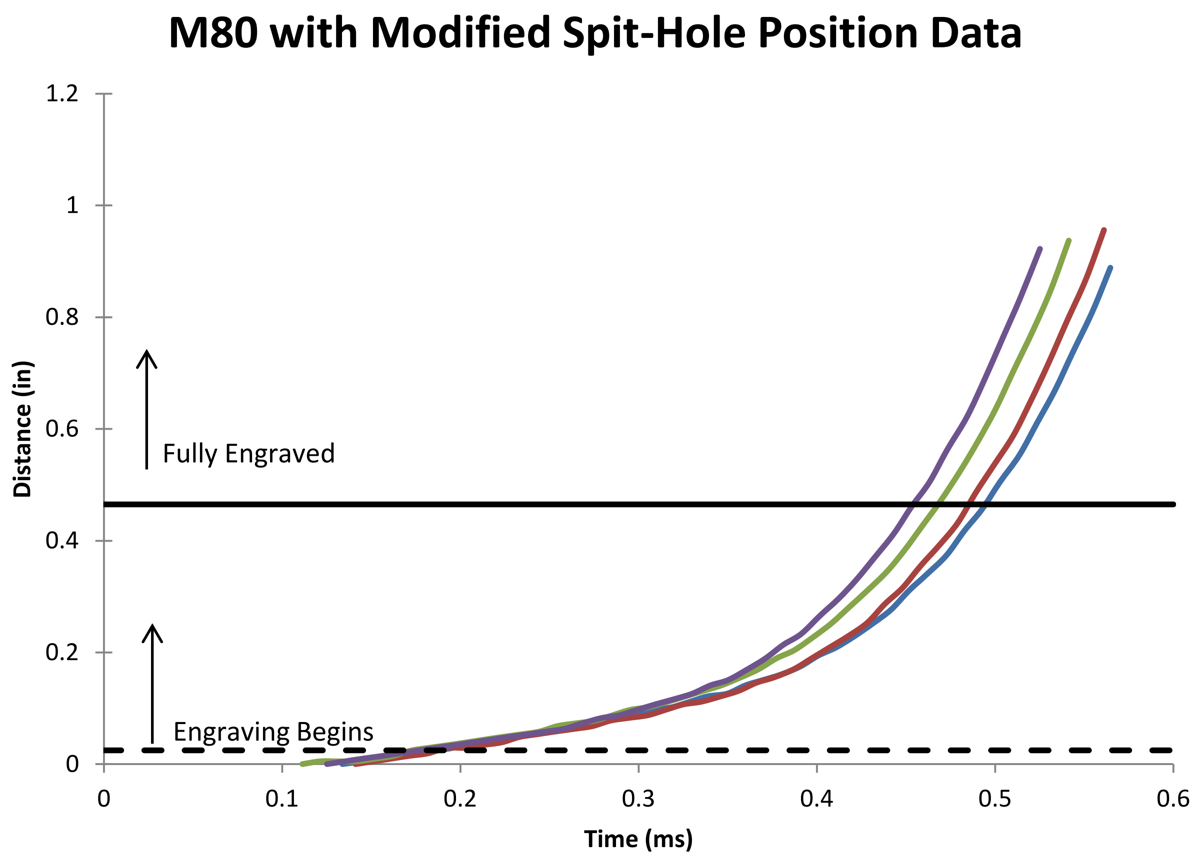

Figure 9. Position data for individual M80 shots with modified spit-hole.

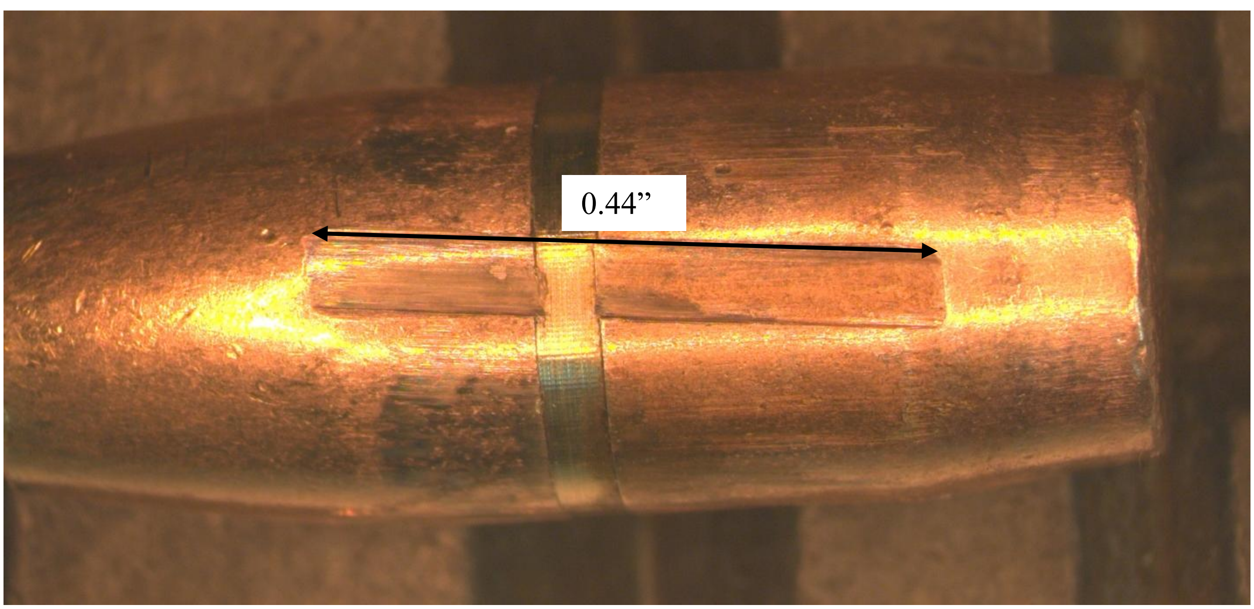

Figure 10. Engraving mark on a recovered projectile.

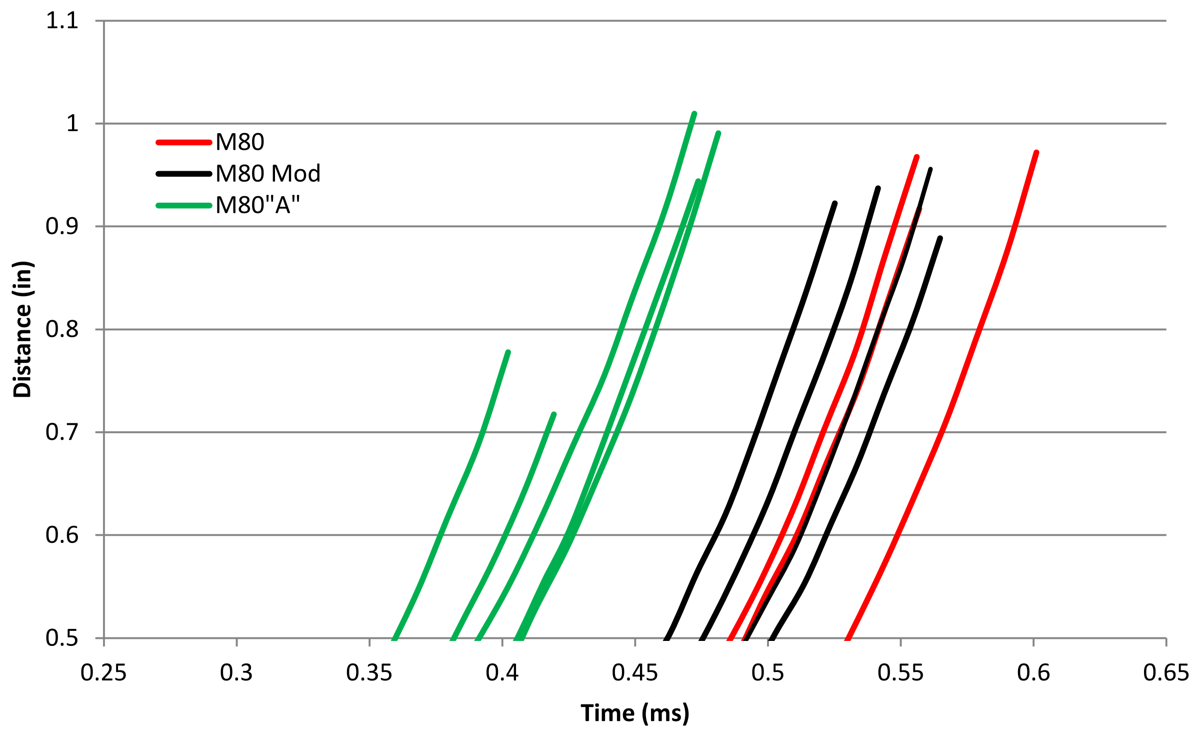

Figure 11. M80, M80 "A," and M80 with modified spit-hole position data after 0.50 in of travel.

4. Conclusion

A 7.62-mm primer force measurement breech design was proven out with standard M80 and M80 "A" cartridges. A subsequent experiment evaluated the influence of reducing the spit-hole area by 50.3% on primer pocket pressure and early motion. The experiments were successful in proving the primer force breech's efficacy in evaluating early time interior ballistics. Through the course of the experiments the M80's no. 34 primer produces very little initial force output. This is contrary to what has been previously observed with the no. 41 primer used in the M855 cartridge. However, when the spit-hole area is reduced the force witnessed in the primer pocket is about three times that of a no. 41 primer and 20 times that of a no. 34 primer with standard spit-hole areas. Similar results were observed in fully loaded cartridges.

The reduction in spit-hole area caused a localized increase in primer cup pressure but did not significantly affect the overall interior ballistic cycle. The decreased area resulted in the propellant charge burning sooner and the projectile moving slightly earlier when compared to the baseline M80, but not by a significant amount. The M80 "A" projectile motion occurred significantly sooner when compared to both M80 variants due to its quicker burning propellant formulation.

Finally, variations associated with the initial engraving process are a potential source of deviations in the 7.62-mm cartridge performance. It is at this point in the ballistic cycle where differences in performance are seen in the short barrel data. After the initial engraving process is completed, the performances measured in the short barrel experiments are consistent.

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Appendix. Velocity Data

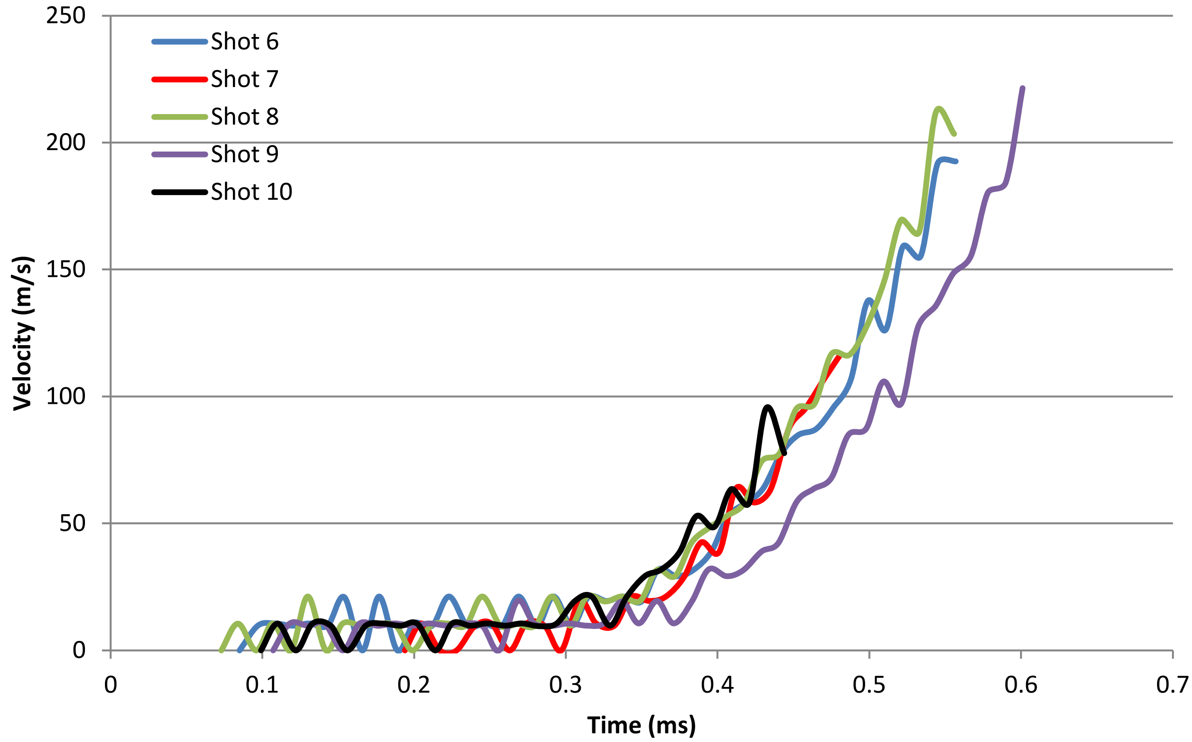

Figure A-1. M80 velocity.

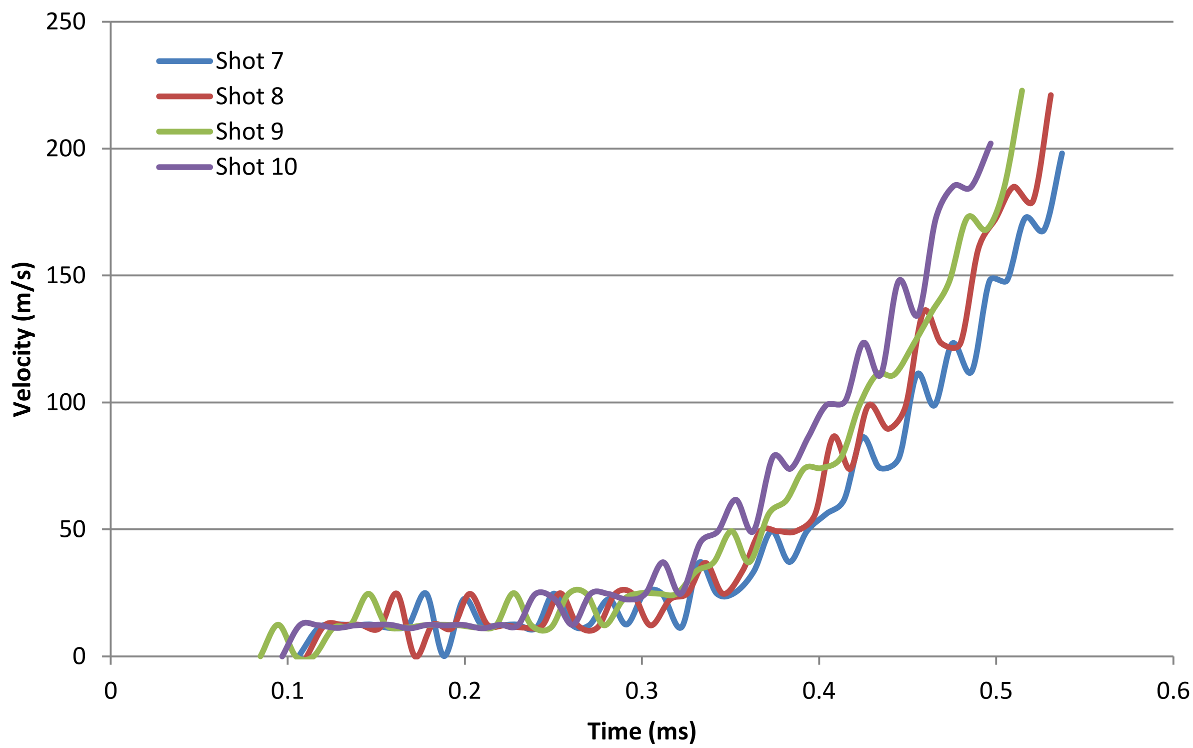

Figure A-2. M80 modified spit-hole velocity.

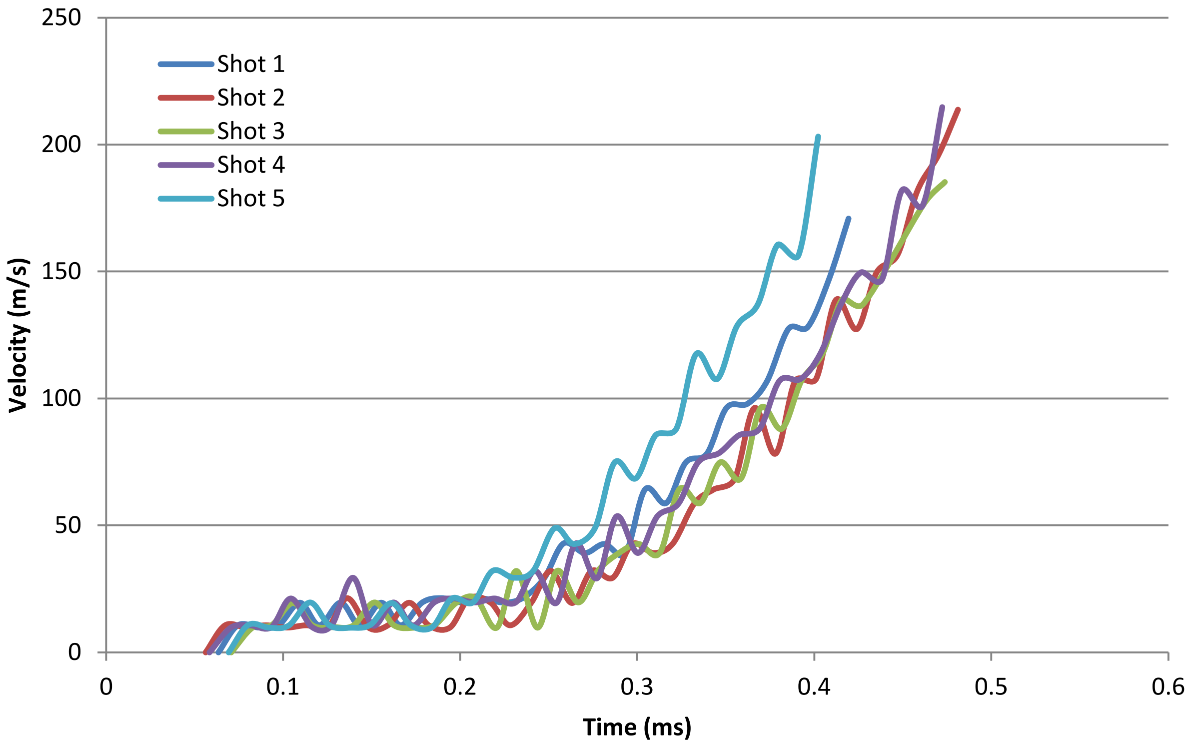

Figure A-3. M80 "A" velocity.

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List of Symbols, Abbreviations, and Acronyms

⌀	diameter
ARL	U.S. Army Research Laboratory
a.u.	arbitrary unit
SD	standard deviation
fps	frames per second
IB	interior ballistics
in	inch
ksi	thousand pounds per square inch
lbf	pound force
mm	millimeter
ms	millisecond
m/s	meters per second
psi	pounds per square inch
μs	microsecond

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